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EXPERIMENTAL INVESTIGATION OF EFFECT OF HEAT TREATMENT ON NOSE RADIUS OF INSERT AND TEMPERATURE AT CUTTING AREA IN TURNING OF TITANIUM (GRADE 2)

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ABSTRACT

Titanium and Titanium alloys are utilized in many aerospace applications due to a combination of properties such as high strength at elevated temperatures and relatively low density. However, these materials are problematic to machine and are therefore referred to as difficult-to-cut materials. Compared to most materials, the chip–tool interface temperatures during machining are extremely high, even at lower cutting speeds, and tend to concentrate close to the cutting edge. These alloys when machined results in the reduced tool life and effects the surface roughness of the material. In this article to overcome the reduction in the tool life and development of the temperature at the cutting area the titanium is heat treated. The temperature at the cutting area in the turning is measured using Non-Contact Infrared Digital Thermometer and the nose radius of the tool insert is measured using profile projector.

Key words: Profile Projector, Tool Insert Nose Radius, Titanium, Heat Treatment.

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1. INTRODUCTION

Titanium and its alloys are considered as important engineering materials for industrial applications because of good strength to weight ratio, superior corrosion resistance and high temperature applicability. Titanium alloys have been widely used in the aerospace and aircraft industry due to their ability to maintain their high strength at elevated temperature, and high

resistance for corrosion. They are also being used increasingly in chemical process, automotive, biomedical and nuclear industry.[1] The machinability of titanium alloys is very poor when compared to both general steels and stainless steels, which imposes particular demands on the cutting tools employed for machining , makes titanium alloys has a topic of great interest for industrial production and scientific research worldwide. During machining, conventional tools wear away rapidly because the poor thermal conductivity of titanium alloys results in higher temperature closer to the cutting edge and there exists strong adhesion between the tool and workpiece material.[2]

With advances in cutting tool materials, many difficult-to-machine materials can now be machined at higher metal removal rates. None of these tool materials, however, seems to be effective in machining titanium because of their chemical affinities with titanium. [3] New development in tool coating also does not help titanium machining. $Al_2 O_3$ Coating has a lower thermal conductivity than the tungsten carbide insert, which prevents heat dissipation from extremely concentrated high stress and high temperature at the cutting point. Titanium carbide and titanium nitride coatings are not suitable for machining titanium alloys because of their chemical affinities. In the present investigation, turning of titanium alloy is carried out on both heat treated and non-heat treated rod and results showed an improvement of tool life and reduction of temperature at cutting area for heat treated rod when compared with the Non-heat treated rod.[4]

2. HEAT TREATMENT OF TITANIUM AND ITSALLOYS

Titanium and titanium alloys are heat treated for several reasons:

- To reduce residual stresses developed during fabrication (stress relieving)
- To produce the most acceptable combination of ductility, machinability, and dimensional and structural stability, especially in alpha-beta alloys (annealing)
- To increase strength by solution treating and aging
- To optimize special properties, such as fracture toughness, fatigue strength, and high-temperature creep Strength[5]

Stress relieving and annealing may be used to prevent preferential chemical attack in some corrosive environments, to prevent distortion, and to condition the metal for subsequent forming and fabricating operations. Hot isostatic pressing, a specialized heat treatment process, can help narrow the fatigue property scatter band and raise the minimum fatigue life of cast components. [6]

3. EXPERIMENTAL DETAILS

3.1. Material Employed

In this investigation commercially available titanium Grade 2 is undertaken. The mechanical properties and chemical composition of the material are given in Table 1 and Table 2 [7] respectively. The material in rod form of 20 mm diameter and 120 mm length is used for the heat treatment, machining and further

Table 1 Mechanical Properties of Titanium Grade 2

Property	Value
Yield Strength	275 Mpa
Ultimate Tensile Strength	345 Mpa
Elongation %	>20 %
Reduction of Area %	>30%

Table 2 Chemical Specification of Titanium Grade 2

Chemical	Value
Carbon, C	< 0.08 %
Iron, Fe	< 0.3 %
Oxygen, O	< 0.25 %
Nitrogen, N	< 0.03 %
Hydrogen, H	< 0.015 %
Titanium, Ti	Balance

3.2. Heat Treatment

The process annealing is carried out for one out of the two rods in the melting furnace at the conditions as specified in the Table 3

Table 3 Conditions for Heat Treatment

Temperature	450 ^{o} C
Time	180 Mins
Type of cooling	Furnace Cooling

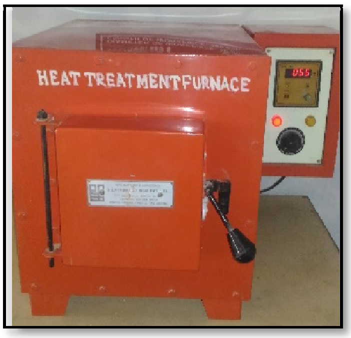

Figure 1 (a) Heat Treatment Furnace Outer view

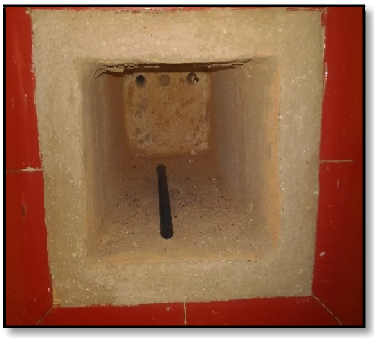

Figure 1 (b) Heat Treatment Furnace Inner view

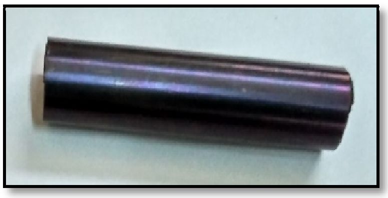

Figure 1 (c) Heat Treated Titanium Rod

3.3. Specifications of Turning Tool Holder and Insert Used in experiments

Sandvik coromant USA made external turning tool holder is used for the machining throughout the experiment. The tool holder is shown in figure 2 and the specifications of the tool holder is shown in the Table 4[8,9]

Figure 2 Tool Holder

Table 4 Tool Holder Specifications

Tool holder name	MTJNR 2020K 16	
Breakdown of tool holder name according to ISO nomenclature		
Letter	**Convection**	**Explanation**
M	Insert clamping method	Top + hole clamping
T	Insert type	Triangle
J	Holder style	27^{o} Auxiliary cutting edge
N	Insert clearance angle	0°
R	Hand of tool	Right
20	Shank height	20 mm
20	Shank width	20 mm
K	Holder length	125 mm
16	Length of insert cutting edge	16 mm

The Sumitomo made triangle coated carbide insert EN10Z is used in the tool holder throughout the experiment. The insert is shown in Figure 3 and specifications are shown in Table 5[10]

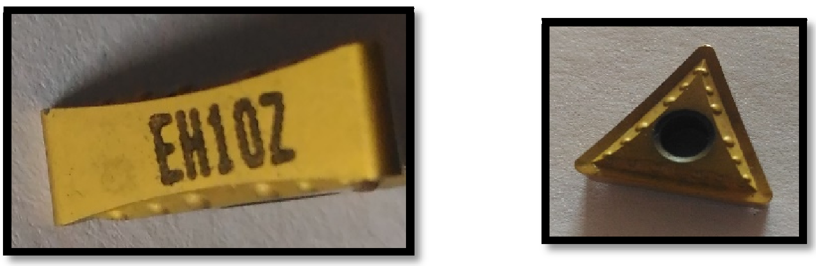

Figure 3 EH10Z Triangle Insert

Table 5 Insert Specifications

<table>
<tr><th colspan="2">Insert name EH10Z</th><th colspan="3">TNGG 160302 R ST</th></tr>
<tr><th colspan="5">Breakdown Insert name according to ISO nomenclature</th></tr>
<tr><th>Letter</th><th>Convection</th><th colspan="3">Explanation</th></tr>
<tr><td>T</td><td>Shape</td><td colspan="3">Triangle</td></tr>
<tr><td>N</td><td>Clearance Angle</td><td colspan="3">0˚</td></tr>
<tr><td rowspan="2">G</td><td rowspan="2">Tolerance on Size</td><td>Inscribed Circle</td><td>Thickness</td><td>Height</td></tr>
<tr><td>± 0.025 mm</td><td>± 0.025 mm</td><td>± 0.13 mm</td></tr>
<tr><td>G</td><td>Insert Cross Section Type</td><td colspan="3">C Sink 70°- 90°</td></tr>
<tr><td>16</td><td>Cutting Edge Length</td><td colspan="3">27 mm</td></tr>
<tr><td>03</td><td>Thickness</td><td colspan="3">3.18 mm</td></tr>
<tr><td>02</td><td>Nose Radius</td><td colspan="3">0.2 mm</td></tr>
<tr><td>R-ST</td><td>Chip breaker Geometry</td><td colspan="3">-</td></tr>
</table>

3.4. Measurement of Temperature at cutting Area

The temperature at the cutting area is measured with the help of infrared thermometer while machining. The device is shown in Figure 4

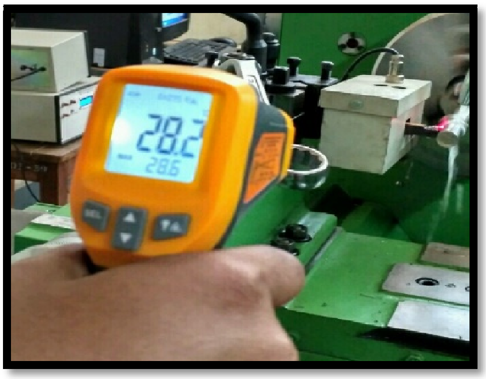

Figure 4 Infrared Thermometer

3.5. Hardness Testing

The hardness test is carried out for the both rods i.e, Heat Treated Rod and the Non Heat Treated on the Brinell Hardness Testing Machine. [11] Testing Details:

Test Procedure : IS 1500: 2005

Type of Hardness : BHN

Indentor : 2.5 mm

Load Applied : 187.5 Kgs

Location : Surface

4. RESULTS AND DISCUSSION

4.1. Hardness Testing

The Table 6 shows the comparison of hardness between Heat Treated and Non Heat Treated Rod

Table 6 BHN Values

	Heat Treated Rod (BHN)	**Non-Heated Rod (BHN)**
Impression 1	210	206
Impression 2	206	212
Impression 3	210	212
Average	208.66	210

4.2. Machining Test

The orthogonal cutting trials were carried out on HMT make High precision Lathe NH 22 (Figure 5) [12], which has a 7 kW motor power and the spindle rotation speed ranges from 40-2040 rpm in forward and 60-1430 rpm in reverse. In this Investigation the parameters depth of cut and Speed are varied [13]. The other parameters like feed, coolant discharge rate , length of cut are kept constant .The machining is done to the both the rods i.e, heat Treated and Non heat treated with the same input parameters and the temperature at the cutting area is noted for each trial. The tool insert is changed after the machining of the Non heat treated rod which helps to compare the change in the nose radius of the tool insert with the help of the Profile Projector (Figure 6) The details of the experiment are shown in the Table 7.

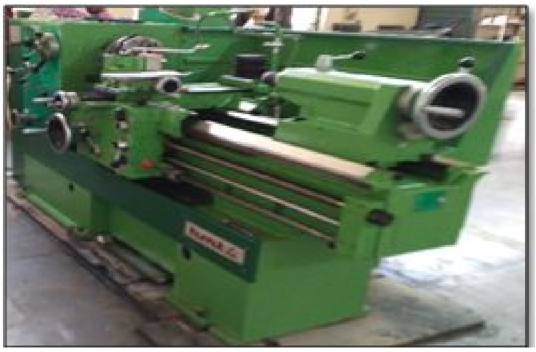

Figure 5 HMT Lathe NH 22

Figure 6 Profile Projector

Table 7 Experimental Input parameters and temperatures measured

Serial No	Feed (mm/rev)	Speed (rpm)	Depth of Cut (mm)	Temperature at cutting Area (˚C)		Reduction in cutting Temperature (%)
				Non-Heat Treated Rod	Heat Treated Rod	
1	0.75	250	0.5	63.6	52.3	17.76
2	0.75	550	0.5	110.7	98.5	11.02
3	0.75	250	1.0	124.4	117.6	5.4
4	0.75	550	1.0	132.2	127.5	3.5
5	0.75	250	1.5	140.9	135.5	3.8
6	0.75	550	1.5	184.6	176.5	4.30

It is recorded low temperature at the tool chip interface with heated material for all the machining parameters compared to non heated material. The reduction in temperature is high at low speeds and depth of cut compared to high speeds and depth of cut. This is attributed due to softening of material with heat treatment and increased easy sheering operation in machining. Similarly the wear rate of the tool at nose in the machining of heat treated rod is very low compared to Non heated rod machining .The results are in tandem with the machining of ferrous materials.

Table 8 Nose Radius of the Inserts before and After Machining

S.No	Type of Insert used	Used for Machining	Nose radius of the Insert		
			Before machining (mm)	After Machining (mm)	% increase in nose radius of insert after machining
1.	Triangle Shaped coated carbide insert	Non-Heat Treated Rods	0.27	0.382	41.48
2.	Triangle Shaped coated carbide insert	Heat Treated Rods	0.27	0.289	7.03

The nose radius of the tool insert is measured before and after machining of both heat treated and non heat treated rods. The Table 8 shows the details of the tool with machining parameters

5. CONCLUSION

The present paper has investigated the effect of heat treatment of the material to be machined with the tool insert nose radius and temperature at the cutting area. The major results can be summarized as follows:

- The temperature at the cutting area is lower when machining the Heat treated Rod compared to the machining of Non heat treated Rod
- Tool insert nose radius had increased when machined Non Heated Rod when compared to the Heat Treated Rod

6. ACKNOWLEDGEMENT

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